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Eddy current testing

Introduction:

Eddy current testing is one of electromagnetic testing methods used in nondestructive testing (NDT). This method is applicable to electrically conductive materials only. Eddy current testing is used in four major areas:

- Detection of surface and slightly sub-surface discontinuities.
- Thickness testing
- Alloy sorting and conductivity testing
- Dimensional measurement.

Description of the method

Eddy currents are created through a process called electromagnetic induction. When alternating current is applied to the conductor, such as copper wire, a magnetic field develops in and around the conductor. This magnetic field expands as the alternating current rises to maximum and collapses as the current is reduced to zero. If another electrical conductor is brought into the close proximity to this changing magnetic field, current will be induced in this second conductor. Eddy currents are induced electrical currents that flow in a circular path, Figure 1. The eddy currents will produce a secondary magnetic field in the sample and, if this secondary magnetic field changes (there may be an interference such as a surface crack for example), then the impedance of the coil will change. These changes in impedance can then be detected and measured.

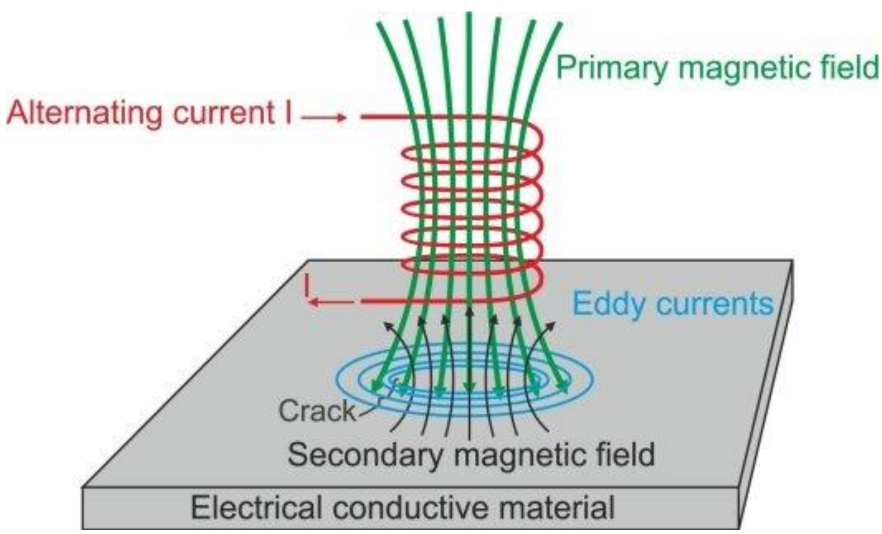

Figure 1. Primary and secondary magnetic field. Eddy current on the test piece

The magnetic field that surrounds the inspection coil is at its strongest next to the coil and gets progressively weaker the further away it is; therefore, the depth of penetration of eddy currents is limited.

Another factor which affects the use of eddy currents is permeability. Some conductive materials are permeable, which means that they can be magnetized. If materials are ferromagnetic, *i.e.* highly permeable, this will lead to inconsistencies in the test results.

The conductivity of a material is an important factor in eddy current testing and the higher the conductivity the more induced current; however, because of this, it produces a stronger secondary magnetic field which opposes the coil's magnetic field more strongly. This strong opposition limits the depth of penetration and therefore the higher the conductivity or permeability, the less the penetration.

Equipment

Eddy current coils basically consist of encircling coils, internal (or bobbin) coils, and probe coils (surface coils), Figure 2.

- **Encircling coil:** The test-piece is passed through an encircling coil, which obviously has a larger outside diameter than the part. Typically, bar, wire, tubes, etc., are tested using encircling coils.

  Circumferential discontinuities are difficult to detect; however, longitudinal discontinuities and outside diameter variations (due to changing fill factor) can be detected. As you can imagine, accurate centering is essential.
- **Internal coils** are used to inspect the inside diameter of tubular objects. These should still be accurately centered and work in a similar way to encircling coils.
- **Probe coils, sometimes called surface coils**, are fitted into a probe, which scans the surface of the test-piece. Probe coils are very sensitive to small discontinuities and can be shaped to fit irregular shapes. However, one disadvantage is a slow scanning speed and only a small area can be tested, as opposed to encircling and internal coils.

The type of coil used depends on the shape and size of the component and the faults for which it is being inspected.

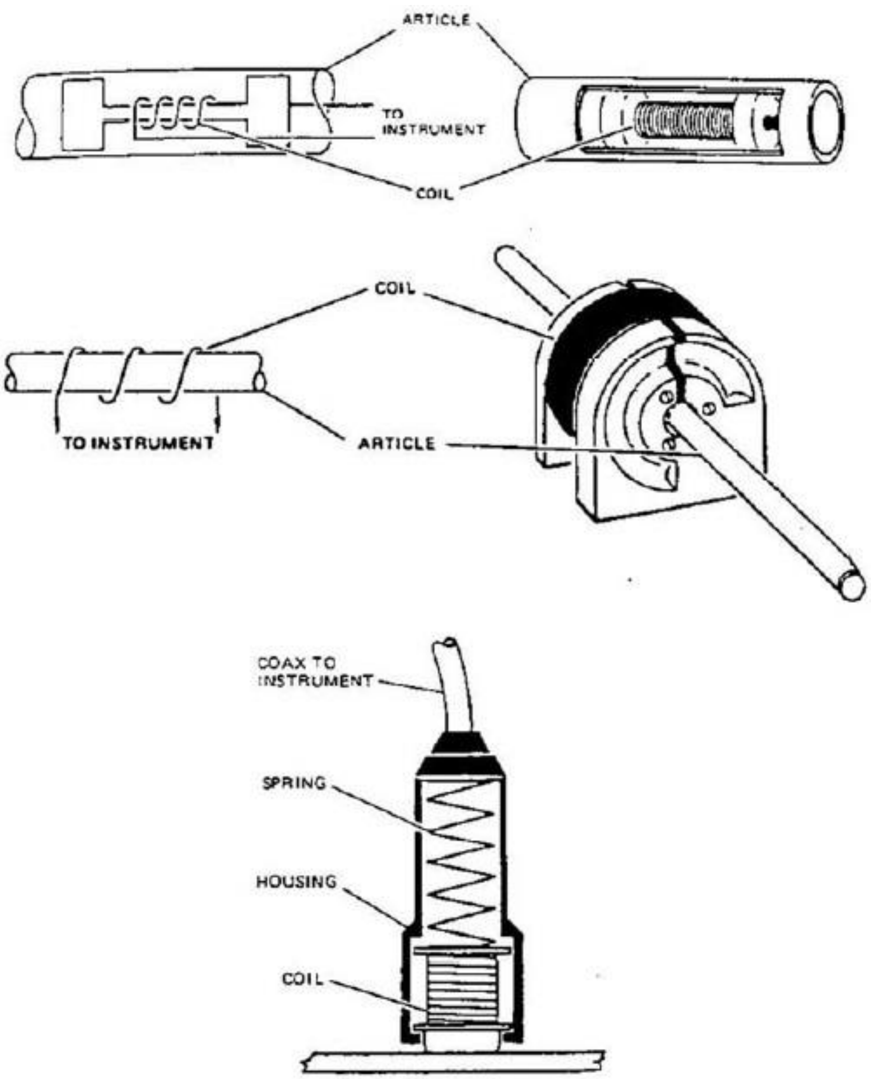

Figure 2: Types of probes used in eddy current testing
a: Internal coils, b: Encircling coil c: surface probe

There are three other terms used in eddy current testing that need to be outlined: lift-off, fill factor and edge effect.

Lift-off

As the eddy current coil is lifted away from the test-piece, less and less of the magnetic flux reaches the test-piece, until at some distance the magnetic flux created by the coil fails to reach the test-piece altogether – this is called the lift-off distance. The requirement for the space between the test-coil and the component under test to be constant is one of the problems of testing complicated shaped samples.

Although lift-off is troublesome in many eddy current applications, it can also be very useful in others. For example, it is possible to use variations in lift-off to measure the thickness of non-conductive coatings.

Fill factor

This is a term used with encircling and internal coils and is based on how well the component being tested fills the encircling coil or how well the internal coil fills the hollow component it is inspecting, Figure 3, and 4.

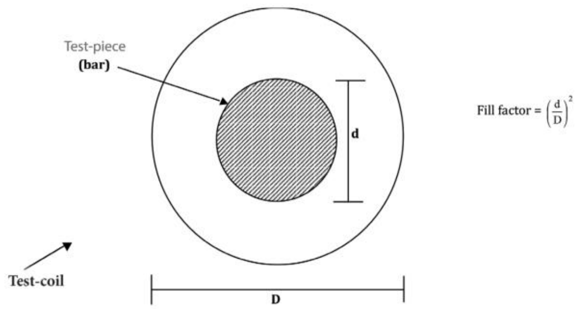

Figure 3 – Encircling coil

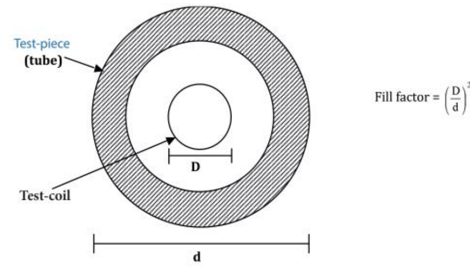

Figure 4 – Internal coil

Edge effect

As an inspection coil approaches the edge of a part being inspected, the eddy currents are distorted as they cannot flow beyond the edges of the test-piece. This results in a non-relevant indication known as the edge effect, Figure 5. This effect needs to be avoided and, to inspect closer to the edge, a smaller diameter coil may be used.

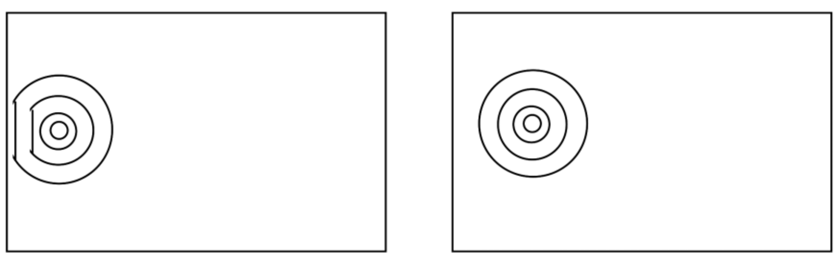

Figure 5 – Edge effect

The following factors change the conductivity of the metal and therefore the results of eddy current testing.

- Adding one or more different metals to produce an alloy of the base metal.
- Changes in the hardness of the metal due to heat treatment.
- Changes in the temperature of the metal.
- Residual stresses in the material.
- The material being clad with a different conductive material.

Advantages

- Eddy current testing can be used to locate and measure a variety of physical properties.
- It can be used as an automated high-speed testing process in some aspects, i.e. encircling coils.
- Eddy currents are very sensitive to small surface cracks if the correct equipment is used.
- Eddy current testing does not require couplant.

Disadvantages

- Eddy currents can only be used on electrically-conductive materials.
- The permeability of ferromagnetic materials gives inconsistent and false readings.
- The depth of penetration is very limited
- When using encircling or internal coils, the part or coil must be accurately centered.
- The indications found are sensitive to orientation, with the most sensitive being when the indication is at 90° to the flow of eddy currents.